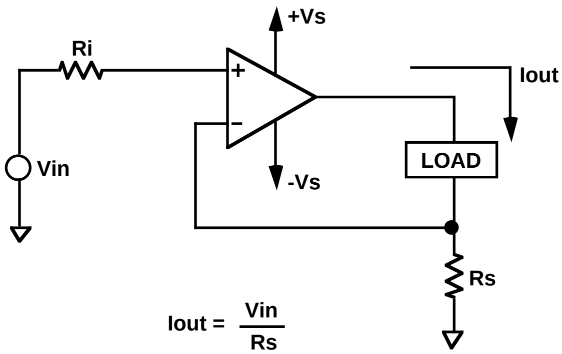
DEFLECTION

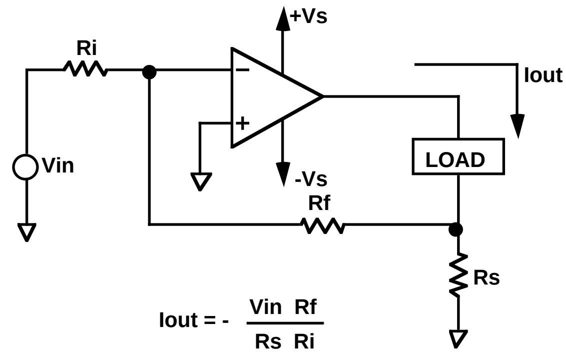
- Electromagnetic
- Electrostatic
- Dynamic Focus Control

High speed power op amps are ideal candidates for all types of deflection uses. High current, high speed models are ideal for electromagnetic deflection. Models with rapid slew rates and extended supply ranges allow rapid dI/dt of the yoke being driven. High voltage models are especially useful for electrostatic deflection and/or focus.

VOLTAGE-TO-CURRENT CONVERSION



NON-INVERTING CONFIGURATION



INVERTING CONFIGURATION

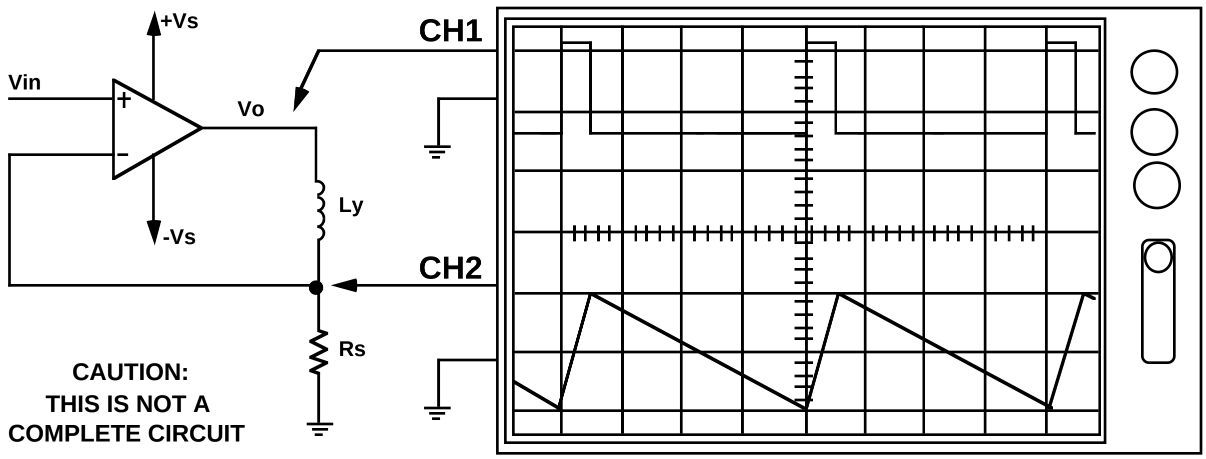
Beam position in magnetic deflection is a function of deflection yoke current. This calls for a current output amplifier.

Two generic examples of voltage-to-current conversion for a floating load are shown here. The floating load circuit provides the best possible performance of any of the current output circuits with the tradeoff that the load must float.

Load current develops a proportional voltage in Rs which is fedback for comparison to applied input.

While simple in theory, an inductive load such as a deflection yoke causes stability complications. The challenge will be to achieve the highest speed possible and maintain stability.

MAGNETIC DEFLECTION
AMPLIFIER SELECTION

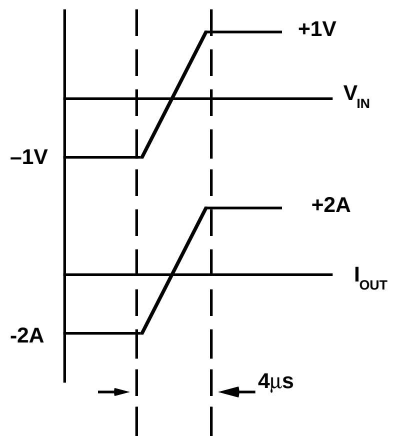


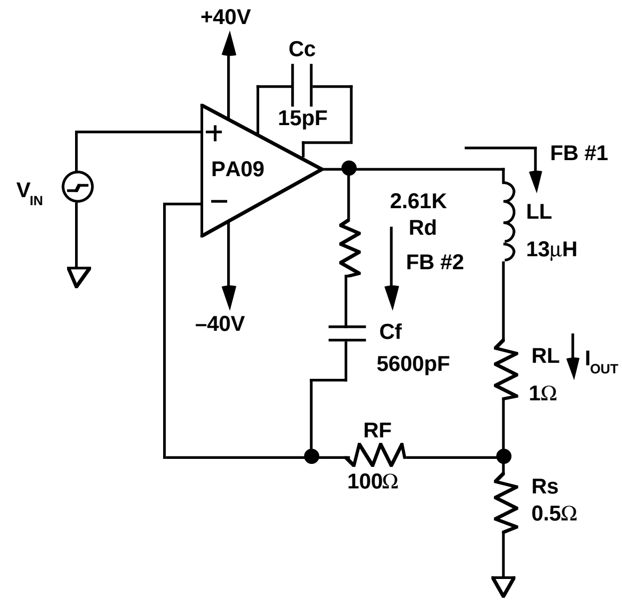
$V_{Rs} = I_O V_{Rs}$ $\qquad$ $V = L \dfrac{di}{dt}$

An amplifier selected for magnetic deflection must have an adequate slew rate and voltage rating to slew the current in the yoke fast enough.

These two considerations go hand in hand since the rate-of-change of current in the yoke is proportional to applied voltage. And the amplifier must slew to this applied voltage at least 10 times faster than the rate of change of current to achieve truly fast and accurate magnetic deflection.

ELECTRONIC DEFLECTION
(V - I CIRCUIT)





DEFLECTION AMPLIFIER SELECTION

STEP 1: VOLTAGE

$V_{LL} = LL \frac{dI_{PP}}{dt}$ $\qquad$ $V_{LL} = 13\mu H \frac{4A}{4\mu s} = 13V$

$V_S = V_{LL} + V_{RL} + V_{Rs} + V_{SAT}$ $\qquad$ $V_{S\,MIN} = 13V + 2V + 1V + 8V$

Where: $V_{RL} = Ip\ RL$ $\qquad$ $V_{S\,MIN} = 24V$

$V_{Rs} = Ip\ Rs$

STEP 2: CURRENT

From desired I_{OUT} current must be 2A.

STEP 3: SPEED

A design rule of thumb, for good performance, is to select an amplifier with a minimum slew rate equal to 10 times faster than the desired current slew rate. Faster will be better.

$$S.R._{MIN} = \frac{V_{S\,MIN}}{(.1)\ dt}$$

$$S.R._{MIN} = \frac{24V}{(.1)\ (4\mu s)} = 60V/\mu s \text{ minimum}$$

STEP 4: FINAL CHOICE IS PA09

$\pm V_S = \pm 40V$

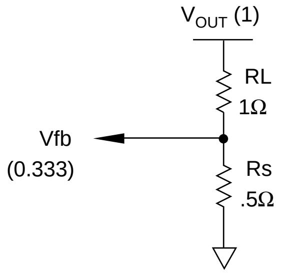
S.R. = > 250V/µs @ C_C = 15pF

I_{LIM} = 4.5A typical

V_{SAT} = 8V @ 2A.

ELECTRONIC DEFLECTION (V-I CIRCUIT)

FB #1
DC BETA
(LL = 0,Cf = ∞)

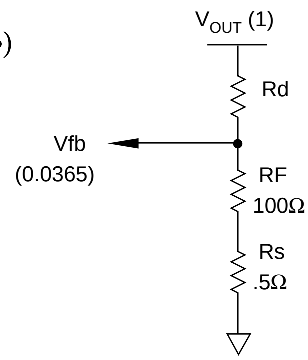


$$\beta = \frac{Vfb}{V_{OUT}} = 0.3333$$

$$\frac{1}{\beta} = 3 \longrightarrow 9.54\text{dB}$$

$$fz1 = \frac{Rs + RL}{2\pi LL} = \frac{0.5\Omega + 1\Omega}{2\pi 13\mu H} = 18.36\text{KHz}$$

FB #2
HI-F BETA
(Cf = 0, LL = ∞)



$$1/\beta \Big|_{\text{HI-F}} = 27.38$$

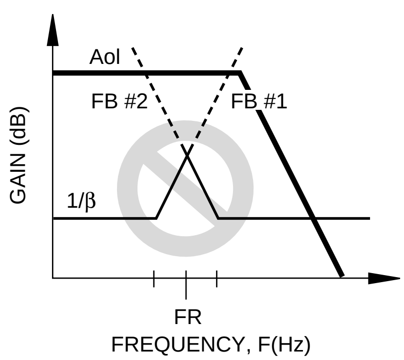
$$\beta = \frac{Vfb}{V_{OUT}} = 0.365$$

Rd = 2.65K
use ⟶ 2.61KΩ

$$fz2 = \frac{1}{2\pi RdCf}$$

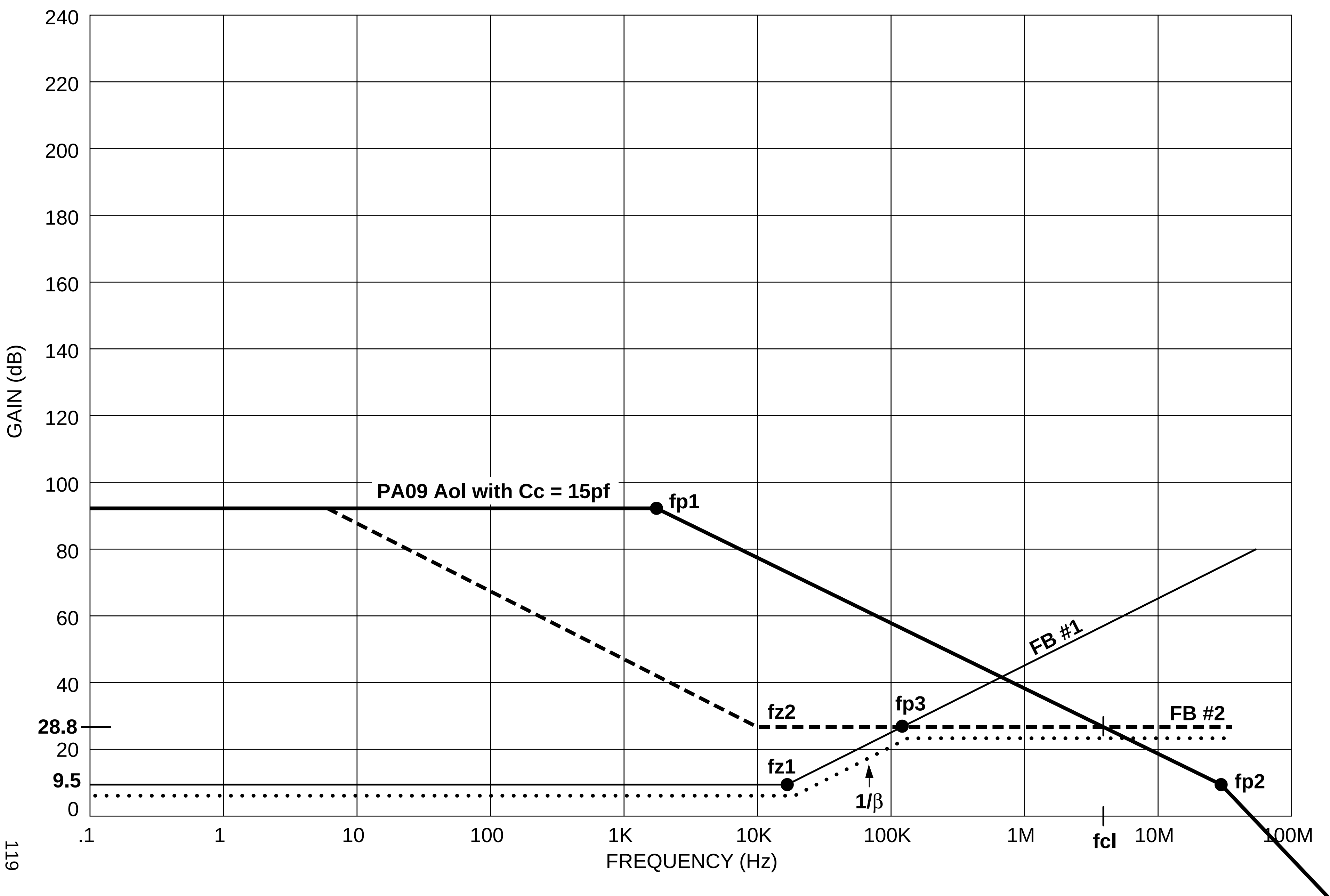
$$10\text{KHz} = \frac{1}{2\pi 2.61\text{KCf}} \longrightarrow \text{Cf} = 6097\text{pF, use } 5600\text{pF}$$

$$fz2 = \frac{1}{2\pi\ (2.61\text{K})\ (5600\text{pF})} = 10.9\text{KHz}$$

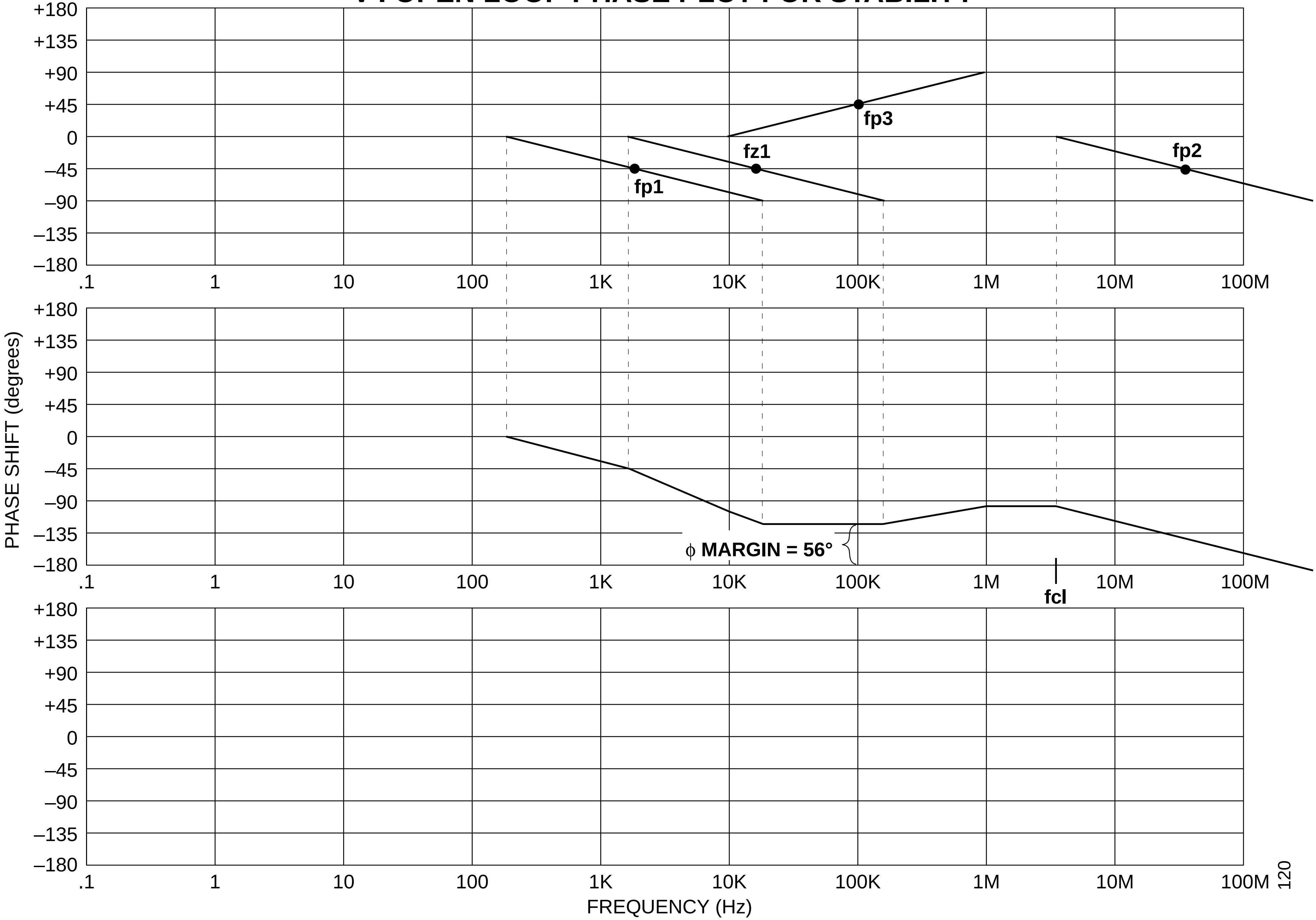


NOTE: IN V to I CIRCUITS AVOID DOUBLE POLE IN 1/β PLOT AF FR. THIS IS A COMPLEX POLE IN THE OPEN LOOP STABILITY PLOT ⟶ –180° PHASE SHIFT. THIS IS CAUSED BY INTERACTION OF LL AND Cf AND FR WILL OCCUR AT $\frac{1}{2\pi\sqrt{LLCf}}$ THIS DOMINATE FEEDBACK PATH, WITH DOUBLE POLE AT FR, WILL CAUSE DESTRUCTIVE OSCILLATIONS IN V to I CIRCUITS.

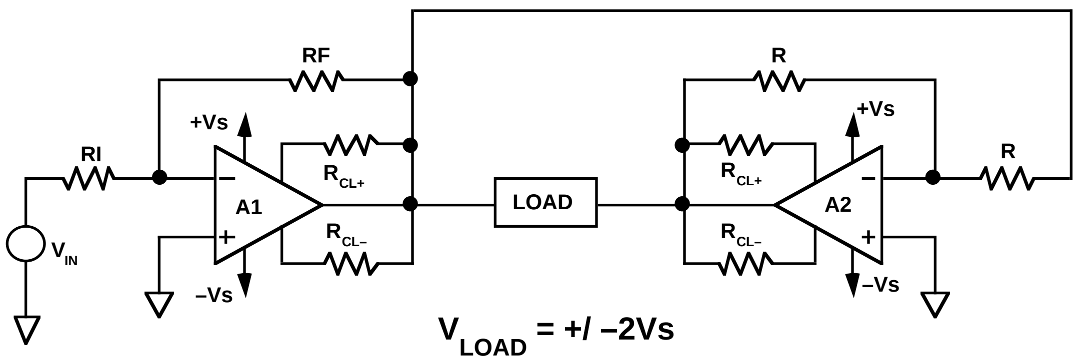
V-I MAGNITUDE PLOT FOR STABILITY



V-I OPEN LOOP PHASE PLOT FOR STABILITY



BRIDGE MODE WITH DUAL SUPPLY
(MASTER/SLAVE)



V_{LOAD} = +/ –2Vs

- **PREVENT SOA VIOLATIONS**
  SET $I_{LIM\ (A2)} > 1.2\ I_{LIM\ (A1)}$
- **BANDWIDTH MISMATCH**

The bridge configuration with dual supplies provides up to double the supply voltage across the load. This has the advantage of using existing supply voltages and yet double the voltage across the load.

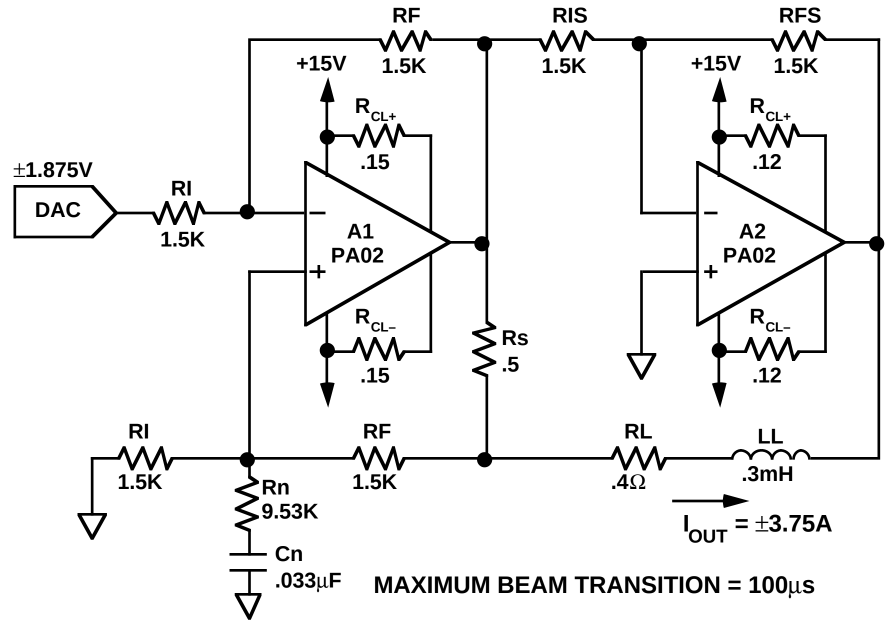
This advantage of the bridge configuration will be used to help drive current into yokes where the V = LdI/dt relationship demands higher voltages for desired performance.

Another advantage of the bridge configuration is that the Slew Rate across the load also gets doubled. This is easiest to see by example. As A1 is slewing up at +10V/µs A2 is slewing down at –10V/µs. This doubling of the slew rate is also advantageous for electromagnetic deflection circuits where an ideal step of output voltage produces a ramp of current in a yoke coil.

SOA stress conditions during the fault condition of a short on the load can be shared equally by both amplifiers in the bridge by setting the current limit of A2 20% higher than A1. This 20% is the worst case, tested difference in current limit set points between any two amplifiers. Forcing the Master amplifier, A1 to current limit first drops its output voltage which in turn drops the output voltage of the slave amplifier, A2. Symmetry is thereby preserved and stresses shared equally.

Since the master amplifier runs in a higher gain than the slave the small signal bandwidth of A1 will be lower than A2. Noise gain compensation can set A2 amplifier's bandwidth equal to A1 if so desired

ELECTRO-MAGNETIC DEFLECTION IMPROVED HOWLAND BRIDGE AMPLIFIER



This bridge electromagnetic deflection circuit utilizes the advantages of two different topologies we have covered. Here we use the Improved Howland Current Pump to drive a load that is tied to a low impedance output of another op amp. We also use the Bridge Mode With Dual Supplies to yield double the voltage and double the slew rate across the yoke load. This topology yields up to 26Vp across the coil with a 40V/µs slew rate. A quick review of our formulae for electromagnetic deflection will verify our circuit is designed properly:

VOLTAGE: $V_{LL} = \dfrac{LL\ dI_{PP}}{dt}$ $\qquad V_{LL} = .3\text{mH}\ \dfrac{7.5A_{PP}}{100\mu s} = 22.5V$

$V_S = \dfrac{V_{LL} + V_{RL} + V_{Rs} + V_{SAT}}{2}$ $\qquad V_{S\ MIN} = \dfrac{22.5V + 1.5V + 1.875V + 2V}{2}$

Where: $V_{RL} = I_{PK}\ RL$ $\qquad V_{S\ MIN} = 13.9375V \approx 14V$

$V_{Rs} = I_{PK}\ Rs$

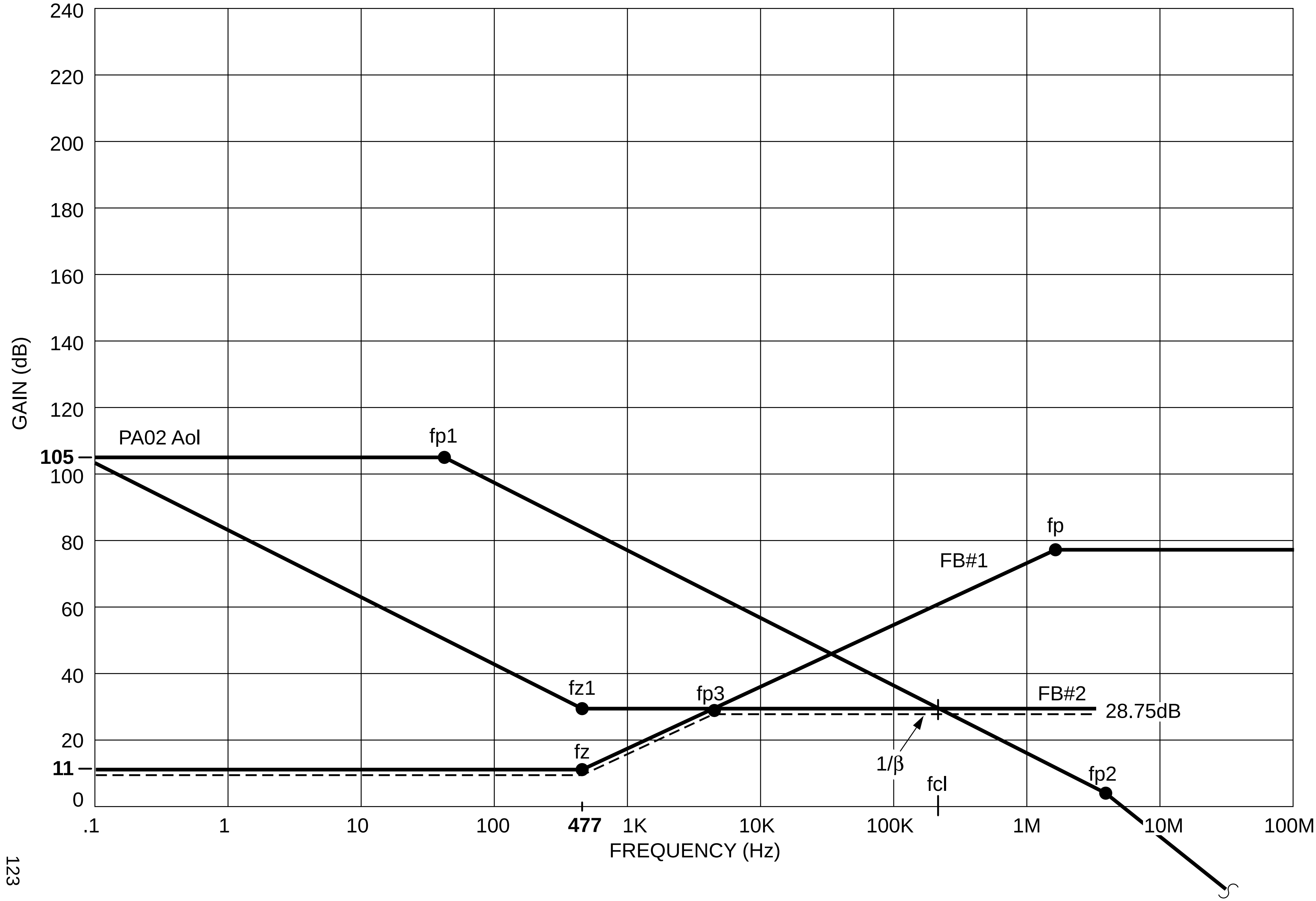
CURRENT: PA02 can handle ±5A ⟶ ±3.75A ok

SLEEP: $S.R._{MIN} = \dfrac{V_{S\ MIN}}{.1\ dt} = \dfrac{14V}{(.1)(100\mu s)} = 1.4V/\mu s$

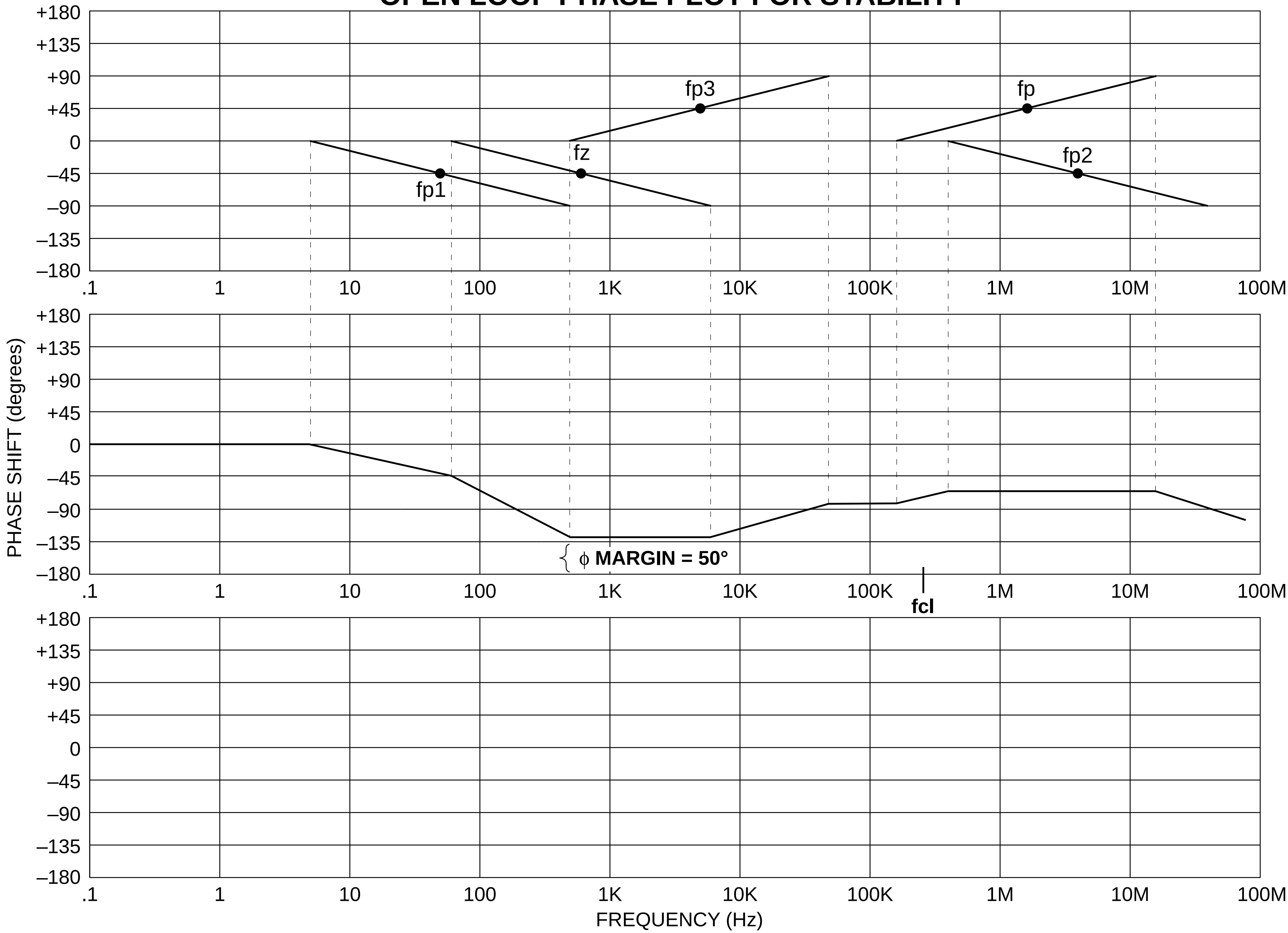
PA02 Slew Rate = 20V/µs ⟶ ok

The results of our calculations show that for the given current change we are voltage limited in this application. A detailed analysis for stability follows.

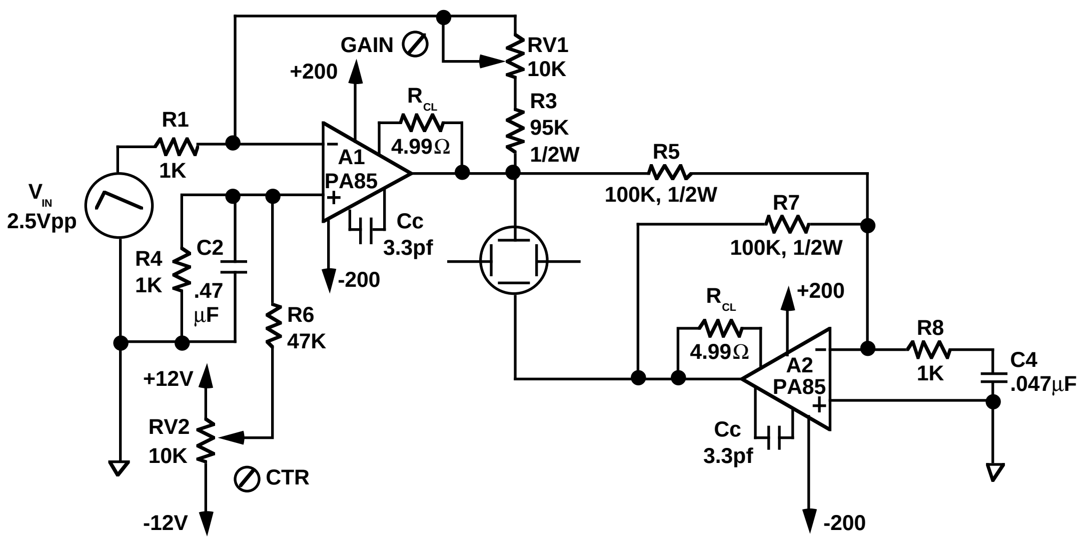
MAGNITUDE PLOT FOR STABILITY



OPEN LOOP PHASE PLOT FOR STABILITY



ELECTROSTATIC DEFLECTION AMPLIFIER



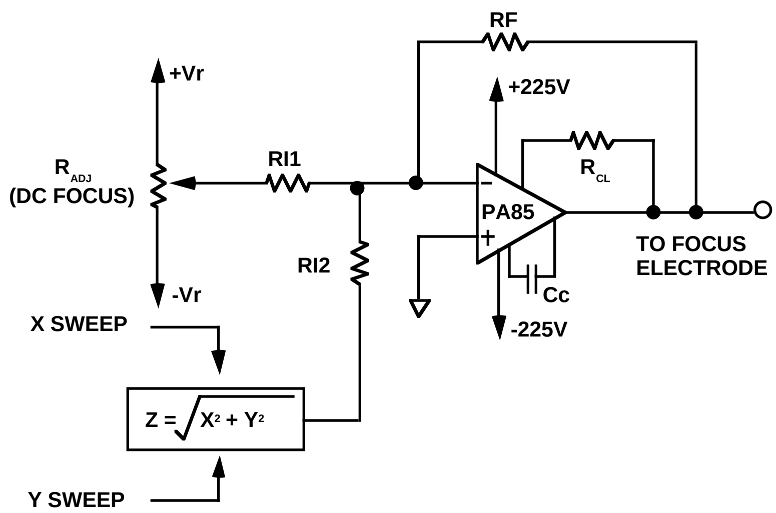
BALANCED TO MINIMIZE CRT DISTORTION

The PA85 was chosen for this application for its high voltage and high speed characteristics. Full bridge drive is utilized to provide a balanced drive to the CRT plate. Bridge drive is useful to reduce geometric distortion in electrostatic deflection applications.

A1 is the main amplifier operating at a gain of 100. This high gain permits minimal phase compensation for maximum speed performance.

Slave amplifier A2 is operated at a feedback factor of 1/2, that is an inverting unity gain. To get the same benefit of high speed that A1 enjoys due to the minimum compensation requirements, A2 is fooled into thinking it has a gain of 100 with the use of R8 and C4. This results in A2 having the same small signal bandwidth and high frequency gain as A1, which allows symetrical bridge slew rates since A1 and A2 now use the same Cc compensation capacitor. This is the “Noise Gain Compensation” trick discussed earlier.

DYNAMIC FOCUSING



RAPID CORRECTION OF FOCUS FOR HIGH RESOLUTION DISPLAYS

In a flat screen display system the distance from the source of the beam to the screen changes as it deflects on the screen, from left to right, and from top to bottom. As a result of this a dynamic focus is required to keep the beam in focus, no matter where it is located on the screen.

A normal CRT screen does not have to overcome these distance differences, since the distance from the source of the beam and the screen are the same no matter where you are on the screen, by virtue of the curvature of the screen.

To achieve electrostatic dynamic focus requires an amplifier with high voltage and high slew rate, as it is important to rapidly change the focus to keep the beam focused, regardless of screen position. The 450V, 1000V/µs slew rate PA85 is the ideal choice.

X and Y location sweep information is summed and scaled to provide the proper focus bias to the focus electrode. A DC offset sets the focus at the center of the screen.

Don't forget the heatsinking on the PA85 as the high slew rate requires a high quiescent current which in combination with the high power supply voltage will result in 11.25W of quiescent power dissipation. A PA85 can cook, from a slew rate standpoint, and will literally cook without proper heatsinking !